PAYLOAD FLIGHT HAZARD REPORT				a. NO:	AMS-02-F07
b. PAYLOAD	Alpha Magnetic Spectrometer-02 (AMS-02)			c. PHASE:	II
d. SUBSYSTEM:	Electrical, Radiation	e. HAZARD GROUP:	Radiation, Injury/Illness	f. DATE:	March 31, 2006
g. HAZARD TITLE:	Excessive Radiated Field Strengths: EMI, Magnetic			i. HAZARD CATEGORY:	CATASTROPHIC X CRITICAL
h. APPLICABLE SAFETY REQUIREMENTS:	NSTS 1700.7B and ISS Addendum, paragraphs 200.2, 212.2				
j. DESCRIPTION OF HAZARD:	The AMS-02 radiates energy fields by way of RF and magnetic fields that may have a hazardous effect on Orbiter Systems, ISS systems and equipment (SSRMS, SPDM), Extravehicular Mobility Unit (EMU), Russian Orlan Suit, Simplified Aid for EVA Rescue (SAFER), EVA tools (including the Pistol Grip Tool) and other safety critical subsystems.				

k. CAUSES

(list)

1. AMS-02 Radiates an Excessive Magnetic Field Strength
2. AMS-02 Radiates an Excessive Electromagnetic Radiation (RF) Field Strength
3. AMS-02 Changing Magnetic Fields induces currents in proximity systems

o. APPROVAL	PAYLOAD ORGANIZATION	SSP/ISS
PHASE I		
PHASE II		
PHASE III		

PAYLOAD FLIGHT HAZARD REPORT		a. NO: AMS-02-F07
b. PAYLOAD Alpha Magnetic Spectrometer-02 (AMS-02)		c. PHASE: II
l. HAZARD CONTROL (CONTROL), m. SAFETY VERIFICATION METHODS (SVM), n. STATUS OF VERIFICATIONS (STATUS)		OPS CONTROL
1. CAUSE: AMS-02 Radiates an Excessive Magnetic Field Strength		
1.1 CONTROL: The AMS-02 Cryomagnet has been designed with multiple magnetic coils oriented to reduce the overall magnetic field outside of the AMS-02 envelope as much as possible. The implementation of precision located racetrack and dipole coils create a large magnetic field (0.86 Tesla/8600 gauss minimum) inside the bore of the Cryomagnet and a greatly reduced field outside. 1.1.1 SVM: The actual magnetic field of the AMS-02 Cryomagnet will be measured and compared to analytic model. 1.1.1 STATUS: Open.		
1.2 CONTROL: The AMS-02 magnetic field profile does not exceed the maximum safe exposure limits for ISS subsystems located within the proximity of the AMS-02 while the AMS-02 Cryomagnet is charged. TIA-310, attached to this hazard report, provides a list of ISS subsystems and the field strength they will likely experience. 1.2.1 SVM: An analysis of the final, measured field strength. 1.2.2 SVM: Program Acceptance of magnetic field strength on ISS Systems. 1.2.1 STATUS: Open. Initial analysis of the predicted field strength has been completed and only requires confirmation of measured field strength to confirm no impact to ISS systems. This is documented in TIA-310. 1.2.2 STATUS: Open. Initial assessment based on the analytic model has been accepted by the ISS Program by the approval of TIA-310. Confirmation of analytic model with measured values will be reported as confirming this assessment.		
1.3 CONTROL: The AMS-02 will only charge the magnetic field or retain it's intense field strength when it is berthed in it's ISS operational location at PAS Site on the S3 truss, upper inboard (PAS 2). Procedure will require that the magnetic field be dissipated prior to any robotic operations removing it from the ISS. The magnet may be discharged through a number of mechanisms, commanded discharge of stored current in a controlled ramp down through AMS-02 Dump Diodes and a controlled quench. In the event that power from the ISS is lost and commanded control is absent the battery powered watchdog timer will initiate a controlled ramp down of the Cryomagnet after 8 hours. A flight rule will be established to assure that the magnet is discharged prior to any grappling by the SSRMS.		I

PAYLOAD FLIGHT HAZARD REPORT	a. NO: AMS-02-F07
b. PAYLOAD Alpha Magnetic Spectrometer-02 (AMS-02)	c. PHASE: II

1.3.1 SVM: Functional demonstration of the ability to dissipate the magnetic field through the AMS-02 Cryomagnet Self Protecting System controlled ramp down.

1.3.2 SVM: Functional demonstration of the ability to dissipate the magnetic field by way of a controlled quench.

1.3.3 SVM: Functional testing of the AMS-02 Cryomagnet Self Protection System/Watch Dog Timer ability to initiate a controlled ramp down in the event of loss of ISS power services.

1.3.4 SVM: Review of AMS-02 Operational Procedures

1.3.5 SVM: Review of Flight Rules.

1.3.1 STATUS: Open

1.3.2 STATUS: Open

1.3.3 STATUS: Open

1.3.4 STATUS: Open

1.3.5 STATUS: Open

1.4 CONTROL: The AMS-02 Cryomagnet cannot be energized within the Shuttle Payload Bay (T>0) as the power provided by the Orbiter can not be supplied to the magnetic field coils without an EVA exchange of cables.

1.4.1 SVM: Review of Design to confirm that APCU power feed cannot power the AMS-02 Cryomagnet charging subsystem.

1.4.2 SVM: Inspection of Flight hardware to confirm EVA accessible cables are configured properly prior to flight.

1.4.1 STATUS: Open.

1.4.2 STATUS: Open.

1.5 CONTROL: The AMS-02 Cryomagnet may be energized through the Shuttle T-0 power feed. There is no plan to initiate charging of the AMS-02 cryogenic magnet while in the shuttle, prior to launch or after. AMS-02 systems will be monitored prior to launch up to L-9 minutes or later to confirm that the AMS-02 Cryomagnet is operationally quiescent. If ground monitoring indicates a charging Cryomagnet or a charged Cryomagnet during launch count down, a No Go will be issued for launch. Once the multiple commands necessary to initiate a charge are issued the AMS-02 Cryomagnet requires 1.5 hours to charge. Monitoring of AMS-02 systems will be accomplished using 1553 and RS 422 communications available through the T-0 Connection.

PAYLOAD FLIGHT HAZARD REPORT	a. NO: AMS-02-F07
b. PAYLOAD Alpha Magnetic Spectrometer-02 (AMS-02)	c. PHASE: II

1.5.1 SVM: Functional Testing of AMS-02 Cryomagnet charging to confirm Cryomagnet charge profile. 1.5.2 SVM: Confirm flight Go/No-Go Procedure/Launch Commit Criteria in place. 1.5.3 SVM: Functional testing of monitoring paths through T-0 lines. 1.5.4 SVM: Ground Operational Procedure and Standards for preflight check of AMS-02 Status for Go-No Go. 1.5.1 STATUS: Open 1.5.2 STATUS: Open 1.5.3 STATUS: Open 1.5.4 STATUS: Open	
1.6 CONTROL: Worst case magnetic fields experienced during an uncontrolled quench will not exceed 175 gauss (1.75 x 10^{-2} Tesla) within the EVA translation path past the AMS-02 (including translations around the AMS-02 associate with adjacent PAS locations). A quench event can produce the worst case magnetic field along the MT translation path for the period of the quench. Nominal AMS-02 magnetic fields will generate the worst case fields (more compact and not dispersed) for other AMS-02 EVA activities (if the magnet was operating). The US EMU, SAFER and PGT have been tested to be compatible with a magnetic field of 600 gauss and have been assessed to be good for a field exposure of 300 gauss (a factor of 2 based on testing). The Russian Orlan suit has been qualified to be compatible with a magnetic field of 175 gauss and will require the AMS-02 magnetic field be dissipated prior to an EVA with the Orlan suit in the immediate proximity to the AMS-02 (accessing the AMS-02, not translations past). The AMS-02 Cryomagnet will have its magnetic fields dumped and power inhibited prior to <u>any</u> EVA procedure to be conducted on/with the AMS-02, a flight rule will be used to assure this occurs. A keep out zone (warning) will be documented to restrict entry into excessive magnetic field strength zones during non-AMS-02 EVA tasks. 1.6.1 SVM: Analytic assessment of uncontrolled quench magnetic field decay. 1.6.2 SVM: Magnetic field mapping of flight AMS-02. 1.6.3 SVM: Magnetic field compatibility testing/assessment for EMU, SAFER, PGT and EVA equipment. 1.6.4 SVM: Confirmation of Operational limits of Orlan suit, compatible with magnetic fields 175 gauss or less. 1.6.5 SVM: Keep Out Zones Assessment for EVA translation paths documented for AMS-02 Magnetic Fields. 1.6.6 SVM: Review of procedure to discharge the Cryomagnet prior to EVA involving proximity and direct EVA operations with the AMS.	I

1.6.7 SVM: Review of ISS Flight Rules. 1.6.1 STATUS: Closed. Space Cryomagnetics Ltd Memo dated January 30, 2004, Titled "AMS Stray Field During Unprotected Quench" 1.6.2 STATUS: Open 1.6.3 STATUS: Closed. “Extravehicular Mobility Unit (EMU) with 12 Volt Accessories and Tools Magnetic Certification Test Report for the International Space Station/Orbiter Environments”, EMU 1 – 13-054, Contract NAS 9-97150, including Field Engineering Memo, FEM-0032 dated 8/4/2000. 1.6.4 STATUS: Open 1.6.5 STATUS: Open 1.6.6 STATUS: Open 1.6.7 STATUS: Open	
1.7 CONTROL: While on the SSRMS the Cryomagnet cannot be charged. Both AMS-02 power feeds are available while on the SSRMS, however the primary power feed the SSRMS is providing can not charge the magnet. The SSRMS would have to be powering the off nominal power supply to the AMS-02 to have any possibility of charging the magnet. While power can be made available to the charging circuit, the Cryomagnet must be commanded to charge and the limited power through the SSRMS must be made available, nominal power is consumed by the thermal protection and monitoring systems. The lack of a 1553 bus connection (as well as RS 422 and fiber optic links, the AMS-02 terminates the Power Video Grapple Fixture 1553 lines and does not connect them to the AMS-02 system) while on the SSRMS precludes a command path and also shuts down (through the CPU) the ability of the J crate to communication with other systems. With the J-Crate waiting for exterior communications the Cryomagnet Avionics Box (CAB) is off and will not be commanded on, inhibiting the command and power paths to the Cryomagnet. The charging process for the superconducting magnet is operationally complex and there are no stored commands on the AMS-02 computer within the J-Crate that can direct AMS-02 wakeup and magnet charging operations. 1.7.1 SVM: Review of design. 1.7.2 SVM: Functional Testing of AMS-02 Avionics. 1.7.3 SVM: Testing of J-Crate and CAB to confirm that lack of communication path connections inhibits crate function.	I

1.7.4 SVM: Review of Robotic Handling Procedures to assure that primary power is nominally used. 1.7.1 STATUS: Open 1.7.2 STATUS: Open 1.7.3 STATUS: Open 1.7.4 STATUS: Open	
1.8 CONTROL: The AMS-02 has three levels of control to preclude introduction of greater than 459A, and hence a more powerful magnetic field. The first is located in the AMS-02 software to preclude operational commands to raise the value. The second exists in the FPGA that establishes a current limit to 457A. The third barrier is in the conditioning circuits that creates a majority voting system that keeps the current limited to 455.5 ± 3.5A. 1.8.1 SVM: Functional testing of software control. 1.8.2 SVM: Functional testing of FPGA logic array. 1.8.3 SVM: Functional testing of majority voting system. 1.8.4 SVM: Functional testing of AMS-02 charging system. 1.8.1 STATUS: Open 1.8.2 STATUS: Open 1.8.3 STATUS: Open 1.8.4 STATUS: Open	
1.9 CONTROL: When discharged, the AMS-02 Cryomagnet will retain a residual field that will be less than 10 gauss (0.0010 Tesla.) 1.9.1 SVM: Residual Magnetic Field Assessment of AMS-02 1.9.1 STATUS: Open	
2. CAUSE: AMS-02 Radiates an Excessive Electromagnetic Radiation (RF) Field Strength	
2.1 CONTROL: AMS-02 has been designed such that conducted and emitted electromagnetic fields remain within the allowable levels for the Shuttle and the ISS. 2.1.1 SVM: The AMS-02 will be tested as a unit at ESTEC for excessive RF energy.	

PAYLOAD FLIGHT HAZARD REPORT	a. NO: AMS-02-F07
b. PAYLOAD Alpha Magnetic Spectrometer-02 (AMS-02)	c. PHASE: II

2.1.2 SVM: Acceptance of EMI Testing Results by NASA EMEP.

2.1.1 STATUS: Open.

2.1.2 STATUS: Open.

3. CAUSE: AMS-02 Changing Magnetic Fields induces currents in proximity systems

3.1 CONTROL: The AMS-02 Cryomagnet can not be energized within the Shuttle Payload Bay (T>0) as the power provided by the Orbiter can not be supplied to the magnetic field coils without an EVA exchange of cables.

3.1.1 SVM: Review of Design to confirm that APCU power feed cannot power the AMS-02 Cryomagnet charging subsystem.

3.1.2 SVM: Inspection of Flight hardware to confirm EVA accessible cables are configured properly prior to flight.

3.1.1 STATUS: Open.

3.1.2 STATUS: Open.

3.2 CONTROL: The AMS-02 Cryomagnet is capable of being energized through the Shuttle T-0 power feed. AMS-02 systems will be monitored prior to launch up to L-9 minutes to confirm that the AMS-02 Cryomagnet is operationally quiescent. If ground monitoring indicates a charging Cryomagnet or a charged Cryomagnet during launch count down, a No-Go will be issued for launch. Under commanded automated charging the AMS-02 Cryomagnet requires 1.5 hours to charge. Monitoring of AMS-02 systems will be accomplished using Mil-Std-1553 and RS 422 communications available through the T-0 Connection.

3.2.1 SVM: Functional Testing of AMS-02 Cryomagnet charging to confirm charging time profile.

3.2.2 SVM: Confirm flight Go/No-Go Procedure/Launch Commit Criteria in place.

3.2.3 SVM: Functional testing of monitoring paths through T-0 lines.

3.2.4 SVM: Ground Operational Procedure and Standards for preflight check of AMS-02 Status for Go-No Go.

3.2.1 STATUS: Open

3.2.2 STATUS: Open

3.2.3 STATUS: Open

3.2.4 STATUS: Open

PAYLOAD FLIGHT HAZARD REPORT	a. NO: AMS-02-F07
b. PAYLOAD Alpha Magnetic Spectrometer-02 (AMS-02)	c. PHASE: II
3.3 CONTROL: The AMS-02 will not be returned to the Shuttle without dispersing the magnetic field prior to robotic handling. 3.3.1 SVM: Review of procedures. 3.3.1 STATUS: Open	I
3.4 CONTROL: Charging and quenching of the AMS-02 Cryomagnet will not induce adverse currents in any closed loop/eddy current susceptible structure in proximity of the Cryomagnet. Note: Effects of induced currents can manifest as electrical transients or structural loads. 3.4.1 SVM: Analysis of magnetic field strength and time rate change to induce currents. 3.4.1 STATUS: Open	
NOTES: 1 Tesla = 10,000 gauss	

ACRONYMS	
°C – degrees Centigrade (Celsius)	MHz – Mega Hertz
amp-m^2 – Amperes per square meter	GHz – Giga Hertz
AMS-02 – Alpha Magnetic Spectrometer - 02	kHz – kilo Hertz
	Hz – Hertz
CAB – Cryomagnet Avionics Box	SW, S/W – Software
CMG – Control Moment Gyroscope	FPGA – Field Programmable Gate Array
CO_2 – Carbon Dioxide	CPU – Central Processing Unit
GSE – Ground Support Equipment	HW, H/W – Hardware
He – Helium	WCA –
MDP – Maximum Design Pressure	A – Ampere
MLI – Multilayer insulation	mT – milli Tesla
MM – (CMG) Momentum Manager	mWb – milli Weber
EMC – Electromagnetic Compatibility	mV – milli Volts
EMI – Electromagnetic Interference	Imax – I (current) maximum
RF – Radiofrequency	CCS -
SPDM – Special Purpose Dexterous Manipulator	mm – millimeter
EVA – Extravehicular Activity	psi – Pounds per square inch
SAFER – Simplified Aid for EVA Rescue	SFHe – Superfluid Helium
EMU – Extravehicular Mobility Unit	SRMS – Shuttle Remote Manipulator Mechanism
PAS – Payload Attach Site (ISS Side of interface)	STP – Standard Temperature and Pressure
APCU – Auxillary Power Control Unit	SVM – Safety Verification Method

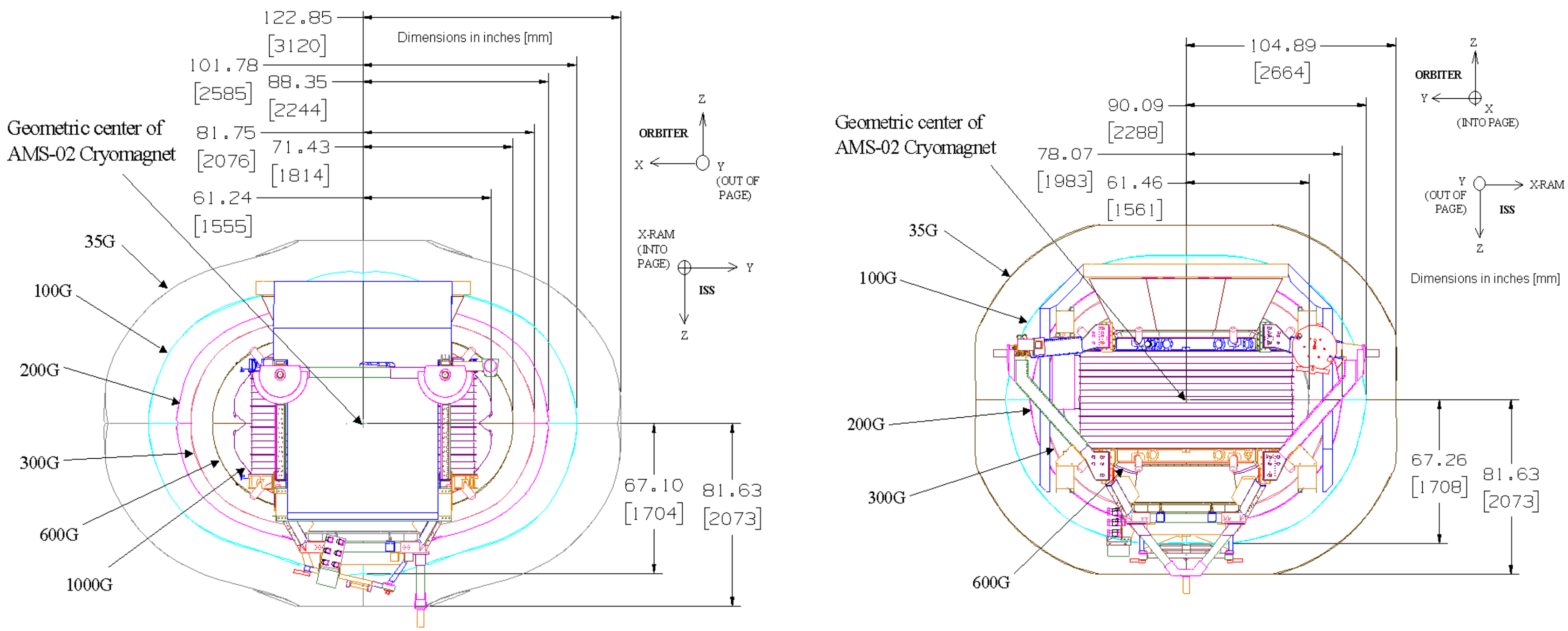
ACRONYMS	
PGT – Pistol Grip Tool	TRD – Transition Radiation Detector
MT – Mobile Transporter	TTCS – Tracker Thermal Control System
SSRMS – Space Station Remote Manipulator Mechanism	USS-02 – Unique Support Structure 02
DC – Direct Current	Xe – Xenon

Electromagnetic Testing

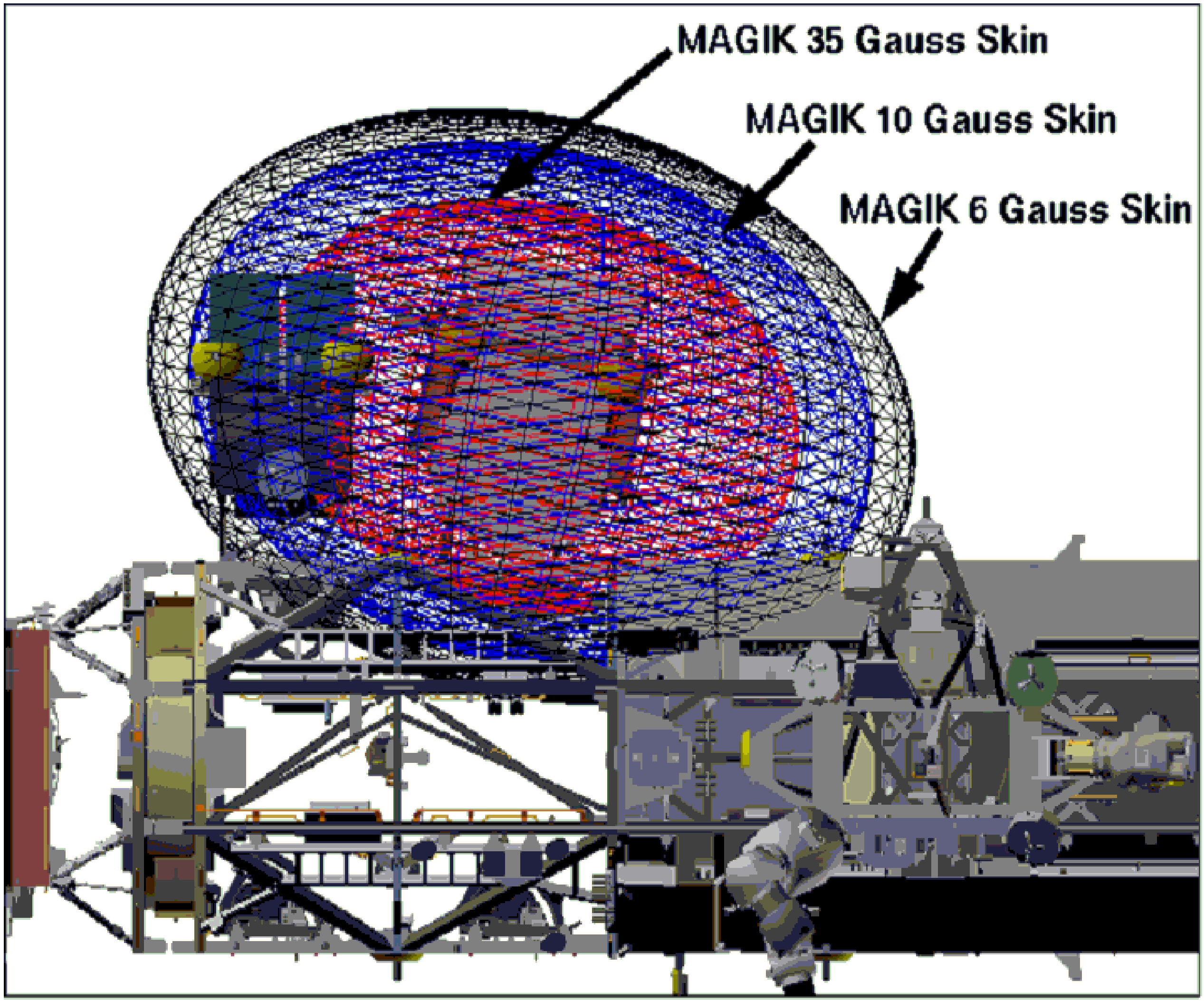
Box Level - SSP 30237			
CE01	Conducted Emissions	DC power, lo freq, 30 Hz to 15 kHz.	DC leads which obtain power from or provide power to other equipment, distribution panels, or subsystems.
CE03	Conducted Emissions	DC power, 15 kHz to 50 MHz.	DC leads which obtain power from or provide power to other equipment, distribution panels, or subsystems.
CE07	Conducted Emissions	DC power leads, spikes, time domain.	DC power leads.
CS01	Conducted Susceptibility	DC power leads, 30 Hz to 50 kHz.	Equipment and systems using DC power.
CS02	Conducted Susceptibility	DC power leads, 50 kHz to 50 MHz.	Equipment and subsystem DC power leads, including power returns that are not grounded internally to the equipment or subsystem.
CS06	Conducted Susceptibility	Spikes, power leads.	Equipment and subsystem DC power leads, including grounds and returns that are not grounded internally to the equipment or subsystem.
RE02	Radiated Emissions	Electric field, 14 kHz to 10 GHz (narrowband), 13.5 -15.5 GHz.	Radiated emissions from equipment and subsystems, cables (including control, pulse, intermediate frequency, power and antenna transmission lines) and interconnecting wiring of the test sample; for narrowband missions, it applies at the fundamental frequencies and all spurious emissions including harmonics, but does not apply for radiation from antennas. This requirement is applicable for narrowband emissions from 14 kHz to 10 GHz and 13.5 -15.5 GHz.
RS02	Radiated Susceptibility	Magnetic induction field	All equipment and subsystems. These susceptibility signals are electromagnetically coupled into the equipment or subsystem wiring.
RS03	Radiated Susceptibility	Electric field, 14 kHz to 20 GHz.	All equipment and subsystems between 14 kHz and 20 GHz. Above 10 GHz, this requirement applies only at specific frequencies and amplitudes known to be present at the Space Station. Below 10 GHz, this requirement shall be increased only at specific frequencies and amplitudes known to be present at the International Space Station (ISS). Module shielding effectiveness can be used to limit the levels applied.

Electromagnetic Testing Continued

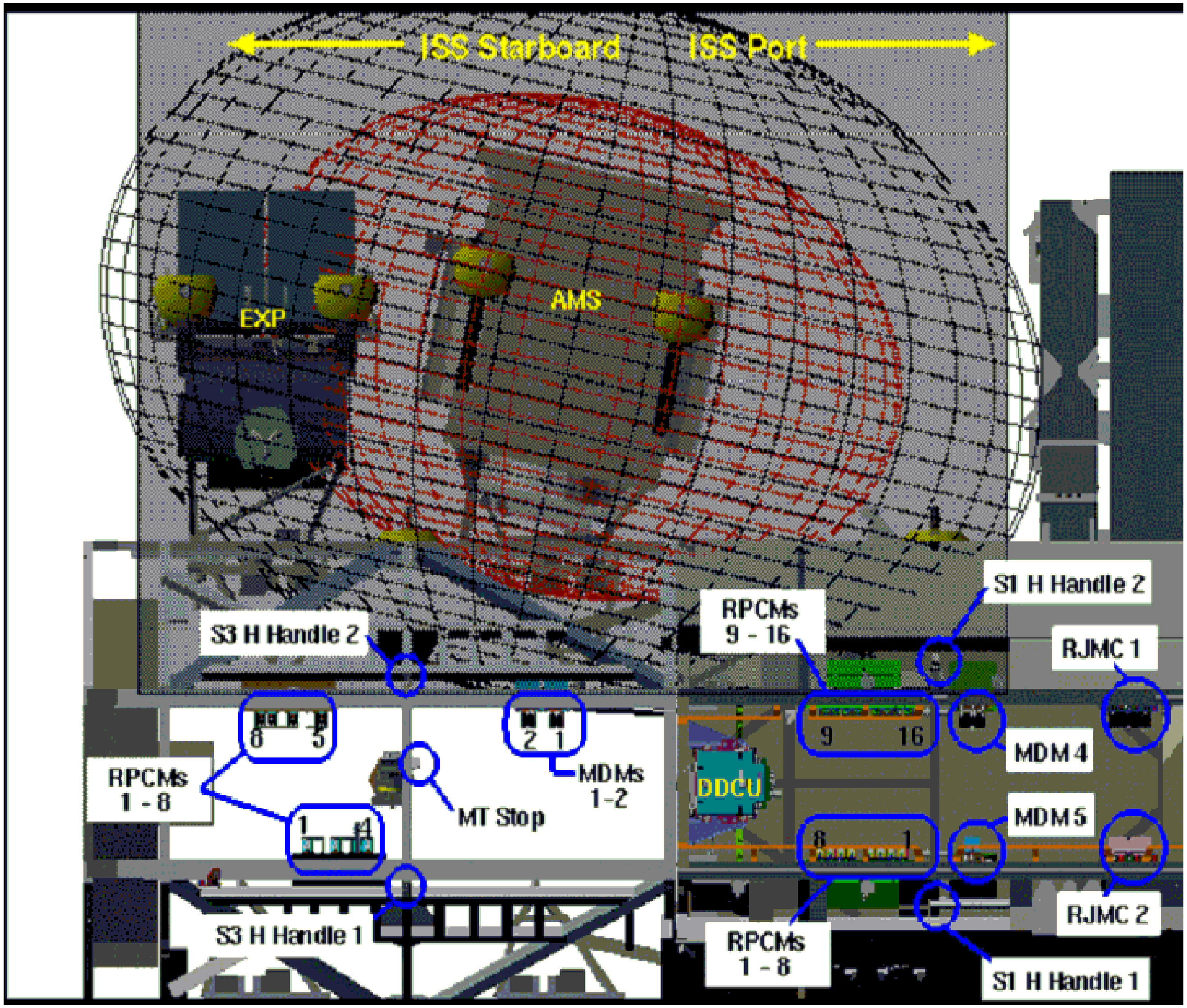
Box Level - SL-E-0002, Book 3			
CE102	Conducted Emissions	Power leads, 10 kHz to 10 MHz	All power leads, including returns, that obtain power from primary sources.
CS101	Conducted Susceptibility	Power leads, 30 Hz to 150 kHz	
CS106	Conducted Susceptibility	Power line switching transients	
CS114	Conducted Susceptibility	Bulk cable injection, 10 kHz to 200 MHz	
CS116	Conducted Susceptibility	Damped sinusoidal transients, cables and power leads, 10 kHz to 10 MHz	
RE102	Radiated Emissions	Electric field, 150 kHz to 18 GHz	
RS103	Radiated Susceptibility	Electric field, 30 MHz to 18 GHz	
TT101	Conducted Emissions, Time Domain	DC power leads, transient and steady state	



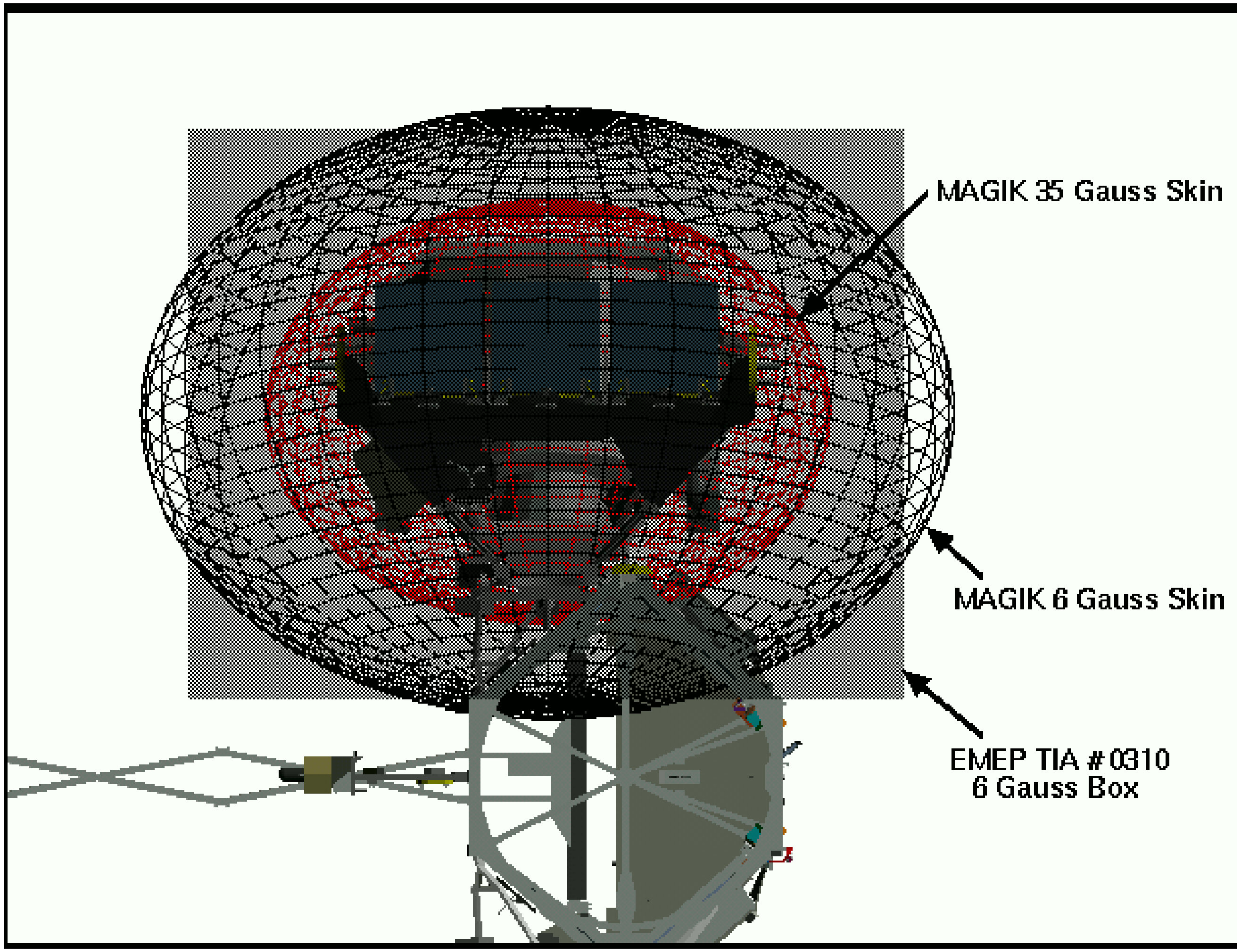
Predicted Magnetic Fields for AMS-02



AMS-02 Magnetic Field
Represented in Magik



AMS-02 Magnetic Field Represented in Magik – ISS Systems Encroachment



AMS-02 Magnetic Field Represented in Magik – 6 Gauss Box

ISS Electromagnetic Effects Panel
Tailoring/Interpretation Agreement

SUBMITTAL DATE	AGREEMENT NO.	REV.	FLIGHT #(s)	
8/22/00	EMEP TIA # 0310	h	UF-4 + 3 years	**PAGE 1 of 3**

SYSTEM	ORIGINATOR and PHONE NO.	ORGANIZATION / CONTRACTOR
Superconducting Magnet	Jim Bates (281) 483-0657	Alpha Magnetic Spectrometer (AMS) Mission Manager/NASA/SF

END ITEM/CONFIG. ID NO.	PART NUMBER(s)	DESCRIPTION	ASSEMBLY(s)
NA	See RATIONALE below.		

SPECIFICATION NUMBER	SPEC. PARAGRAPH NO.	MANUFACTURER	CRITICALITY
SSP 30237	D.5	ETH, Zurich	

ISSUE DESCRIPTION: (use continuation pages if required)
The AMS magnetic field strength violates the following ISS requirement from SSP 30237:

D.5 Direct Current (DC) Magnetic Fields
The generated DC magnetic fields shall not exceed 170 dB above 1 picotesla (3.16 gauss) at a distance of 7 cm from the surface of the equipment. This applies to electromagnetic and permanent magnetic devices.

A similar requirement is stated in SSP 57003, Attached Payload Interface Requirements Document, para. 3.2.2.4.7.

The Alpha Magnetic Spectrometer (AMS) payload has a super-fluid helium superconducting magnet and will be attached to the S3 truss inboard zenith Payload Attach System (PAS) site. The AMS will launch on UF-4 and will remain on-orbit approximately 3 years. The magnetic field strength is approximately 8600 gauss at its centroid, however, diminishes rather quickly. The magnetic field is non-spherical (~ hour-glass shaped), and a detailed map has been delivered to OZ. The magnetic maximum field strength at the magnet's vacuum case outer surface is approximately 2000 gauss.

TAILORING /INTERPRETATION AGREEMENT: (use continuation pages if required)
The Alpha Magnetic Spectrometer (AMS) payload is allowed to exceed the SSP 30237, paragraph D.5 of 170 dB above 1 picotesla (3.16 gauss) at a distance of 7 cm from the surface of the equipment with a level as defined by the magnetic field map delivered to OZ in October, 1999. The magnetic maximum field strength at the magnet's vacuum case outer surface is approximately 2000 gauss. Although the Truss will be almost completed by the time AMS is launched, AMS will have to accept shutdown of operations in the event unevaluated Criticality 1 H/W is brought into the generated magnetic field. In the event that shutdown of the AMS is considered undesirable then AMS will have to fund the necessary work to qualify the equipment in question to operate in the generated environment.

RATIONALE: (use continuation pages if required)
Preliminary analysis data identifying ISS components in the vicinity of AMS that may be adversely affected by the AMS magnetic field have been provided. Susceptible ISS components in the vicinity of AMS include: 1F70141-1 (UMA), 1F70147-1 (CLA), 10033194-501 (External TV Camera), and A05A0298-1 (Video Luminaire Assy). In addition, the SSRMS and SPDM robotic systems, as well as the Russian orlon EVA suits should be evaluated for magnetic field susceptibility limits. (EMU, SAFER, PGT, and sub-assemblies performance were recently tested at NASA JSC for magnetic field susceptibility limits and test results are available for EME Board review.)

Magnetic susceptibility testing and/or analysis of the above components should be performed to validate their performance limits. (Continued)

AGREEMENT DISPOSITION

PRIME EME	NASA EME	DATE	APPROVE	WITHDRAW	REJECT
K. Rice	M. McCollum	10/24/01	Approved		

Concurrence Need Date:

COMMENTS: (use continuation pages if required)
9/5/00 Deferred for analysis of effects of Magnetic Field
1/9/01 Analysis to be completed by cob 1/12/01
1/23/01 Analysis delayed until 2/6/01
2/20/01 Deferred until 3/6/01 EMEP
3/6/01 Deferred until review of test results
10/24/01 Approved Out of Board

ISS Electromagnetic Effects Panel
Tailoring/Interpretation Agreement Continuation Page

SUBMITTAL DATE	AGREEMENT NO.	REV.	FLIGHT #(s)	
8/22/00	EMEP TIA # 0310	h	UF-4 + 3 years	PAGE 2 of 3

SYSTEM	ORIGINATOR and PHONE NO.	ORGANIZATION / CONTRACTOR
Superconducting Magnet	Jim Bates (281) 483-0657	Alpha Magnetic Spectrometer (AMS) Mission Manager/NASA/SF

Type in Heading of Each Continuation Paragraph **CANADIAN SPACE AGENCY TECHNICAL RESPONSE:**

Definition of MSS keep-out zone in relation to the AMS experimental payload.

The following defines a "keep-out zone" for all MSS mobile equipment (SSRMS, SPDM and MBS).

Should space-station operations require any part of the MSS hardware to enter the defined zone, then the AMS magnet shall first be powered down to avoid any possible adverse effects, and shall only be re-powered after the zone is vacated.

Using the S0 coordinate system of the ISS, and units of inches, the AMS is planned to be located as follows:

Upper Inboard Payload Attach System is at (-33.7, 854.3, -80.9)
The offset to the center of the magnet is (0 , -13.4, -71.9)
Location of magnet center is therefore at (-33.7, 840.9, -152.8)
(The AMS magnetic field is tilted 12 degrees towards inboard.)

In relation to the above defined magnet center, the "keep out zone" is defined as follows:

X-axis (ram-wake direction): plus or minus 152 inches
Y-axis (along the truss): plus or minus 170 inches
Z-axis (earth-space direction): plus or minus 121 inches

Supporting Rationale

Since the MSS design requirement included no magnetic design requirements or related test requirements, then in the absence of any detailed knowledge of the equipment's sensitivity in this regard, it has to be assumed that fields much stronger than the Earth's normal magnetic field might have an adverse effect. Common sense dictates that levels up to approximately ten times the Earth's normal field are of no concern, since these are relatively low levels. Thus the "keep out zone" is based on a 6G (six Gauss) magnetic field strength level.

Rationale: (Continued)
The issue regarding interference between the AMS magnetic field and the ETVCG video camera has been resolved via an operational work around. The resolution was presented to the Chief Engineer's Review out of board on October 11, 2001. The text of this message is included below: (A diagram of the camera locations is available in the TIA folder)

The issue "AMS magnetic field interference with truss mounted equipment" is scheduled for the CER tomorrow, 10/11/01. However, new information on this issue indicates that this problem has been solved operationally by MOD.

The truss mounted equipment of concern are the external cameras and Wireless Video System (WVS). A camera or WVS equipment located at the camera port nearest to AMS (Camera Port 2) would be subjected to an 80 Gauss DC magnetic field when AMS is operating. The current MOD plan for use of the external camera ports excludes use of Camera Port 2 due to proximity to AMS (see attached diagram). PICB action items 1111, 1112, and 1113 pertaining to the assessment of implementation and long term use plan for camera port utilization were closed on 9/27/01. Neldon Costin / D014 (originator of the diagram below) confirmed that this plan will be documented in the operations baseline for each flight and that Camera Port 2 is not planned to be used. The operations baseline will require approval of the program office and the flight director.

Camera Port 2 is the only camera port within the area exposed to 6 Gauss or greater from the AMS magnetic field. No camera or WVS External Transciever Assemblies (WETA) are planned to be placed in this port. Camera Port 1 is nearby on S3, however it outside the 6 Gauss area.

This issue appears to be resolved by operational plans.

ISS Electromagnetic Effects Panel
Tailoring/Interpretation Agreement

SUBMITTAL DATE	AGREEMENT NO.	REV.	FLIGHT #(s)	
8/22/00	EMEP TIA # 0310	h	UF-4 + 3 years	PAGE 2 of 3

SYSTEM	ORIGINATOR and PHONE NO.	ORGANIZATION / CONTRACTOR
Superconducting Magnet	Jim Bates (281) 483-0657	Alpha Magnetic Spectrometer (AMS) Mission Manager/NASA/SF

TECHNICAL CONCURRENCE PAGE*

MEMBERS

NAME	DATE	ORGANIZATION
________________	__________	Space Station Hardware Integration Office, KSC
________________	__________	Payloads Office, ISSP
________________	__________	Engineering Directorate, JSC
________________	__________	Safety and Mission Assurance/Program Risk Office, ISSP
________________	__________	Independent Assessment Office, ISSP
________________	__________	NASA Frequency Management Office
________________	__________	Boeing –Houston
________________	__________	Boeing Development Site (s)
________________	__________	
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AD HOC MEMBERS

________________	__________	Space Shuttle Program
________________	__________	Operations Office, ISSP
________________	__________	Subsystem or Tech. Discipline Area Requirement Owner, NASA ISSP
________________	__________	Subsystem or Tech. Discipline Area Requirement Owner, Boeing ISSP
________________	__________	Manager, ISSP Element
________________	__________	Launch Package/Stage Manager
________________	__________	Mission Operations Directorate, JSC
________________	__________	International Partner Representative(s)
________________	__________	
________________	__________	
________________	__________	

Technical Report

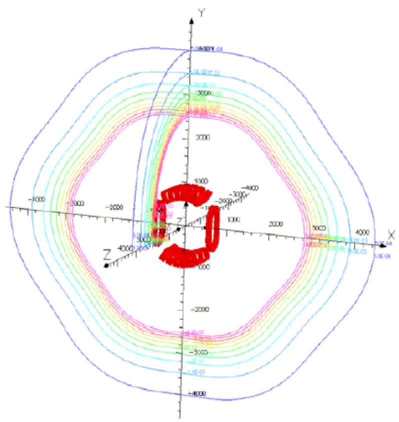
Space Cryomagnetics

Subject:	AMS Stray Field During Unprotected Quench	Author:	S.R.Milward
Ref:	p:\ams\srm\quench\quench safety\stray fields.doc	Date:	30th Jan '04
Dist:		CC:	

Contours of magnetic induction are plotted for various current density combinations in the AMS coils representing fault conditions arising from a failure of the Cryomagnet Self Protection system and then a failure of the magnet ground plane insulation leading to a short circuit between a section of the magnet and the magnet structure. This is a so called "Unprotected Quench".

Normal Operation

Firstly we plot the stray field for the normal full field operating condition of the magnet; current densities are 122.75 A mm^{-2} in the racetrack coils and 125.75 A mm^{-2} in the dipole coils.



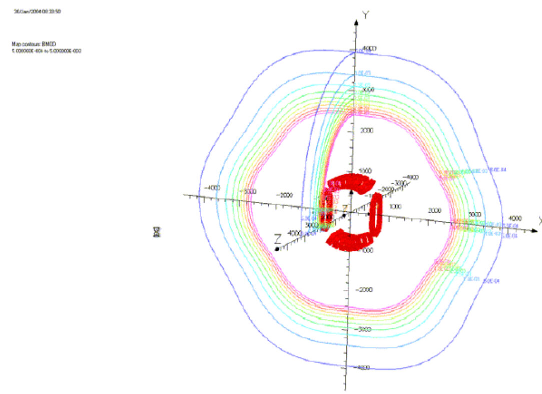
VECTOR FIELDS

Ten contour lines are included between 0.5 mT (5 gauss) and 5 mT (50 gauss) showing that the 0.5 mT line is within 5 m of magnet centre along the x-axis and within approximately 4 m along the y an z-axes.

Short Circuit to Magnet Structure

After 3.5 seconds

It takes a few seconds for significant differences to develop between coils but after 3.5 seconds we have 93.57 A mm^{-2} in the racetrack coils, 83.68 A mm^{-2} in the quenched dipole coil, and 94.26 A mm^{-2} in the other dipole coil:

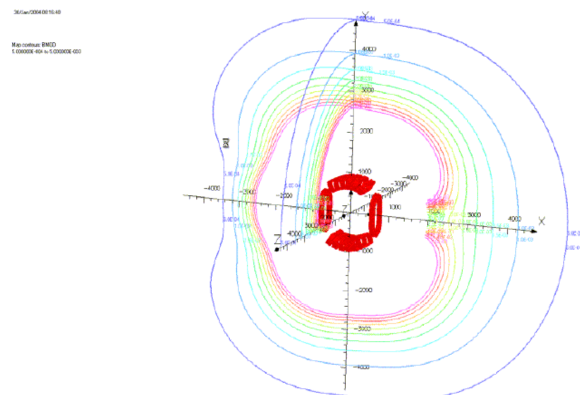


VECTOR FIELDS

Field contours remain much as for normal field operation.

After 4 seconds

95.07 A mm^{-2} in the racetracks, 31.95 A mm^{-2} in the quenched dipole and 95.77 A mm^{-2} in the other dipole:

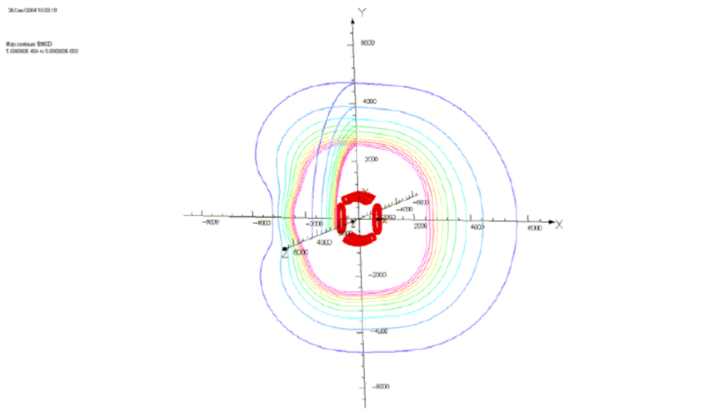


VECTOR FIELDS

Significant asymmetry can be seen in the 0.5 mT field contour which extends to just greater than 5 m in the positive x-direction and to just less than 5 m along the y-axis.

After 4.5 seconds

78.9 A mm^{-2} in the racetracks, 13.5 A mm^{-2} in the quenched dipole and 79.6 A mm^{-2} in the other dipole:

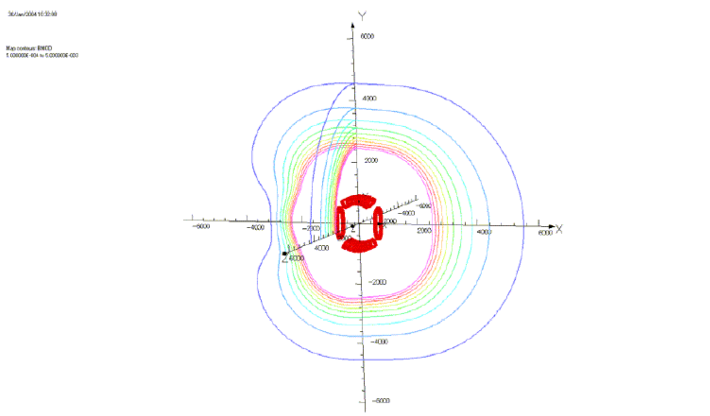


VECTOR FIELDS

Stray field along the x-axis has increased slightly with the 0.5 mT line approaching 6 m.

After 5 seconds

66.0 A mm^{-2} in the racetracks, 5.13 A mm^{-2} in the quenched dipole and 66.5 A mm^{-2} in the other dipole:



VECTOR FIELDS

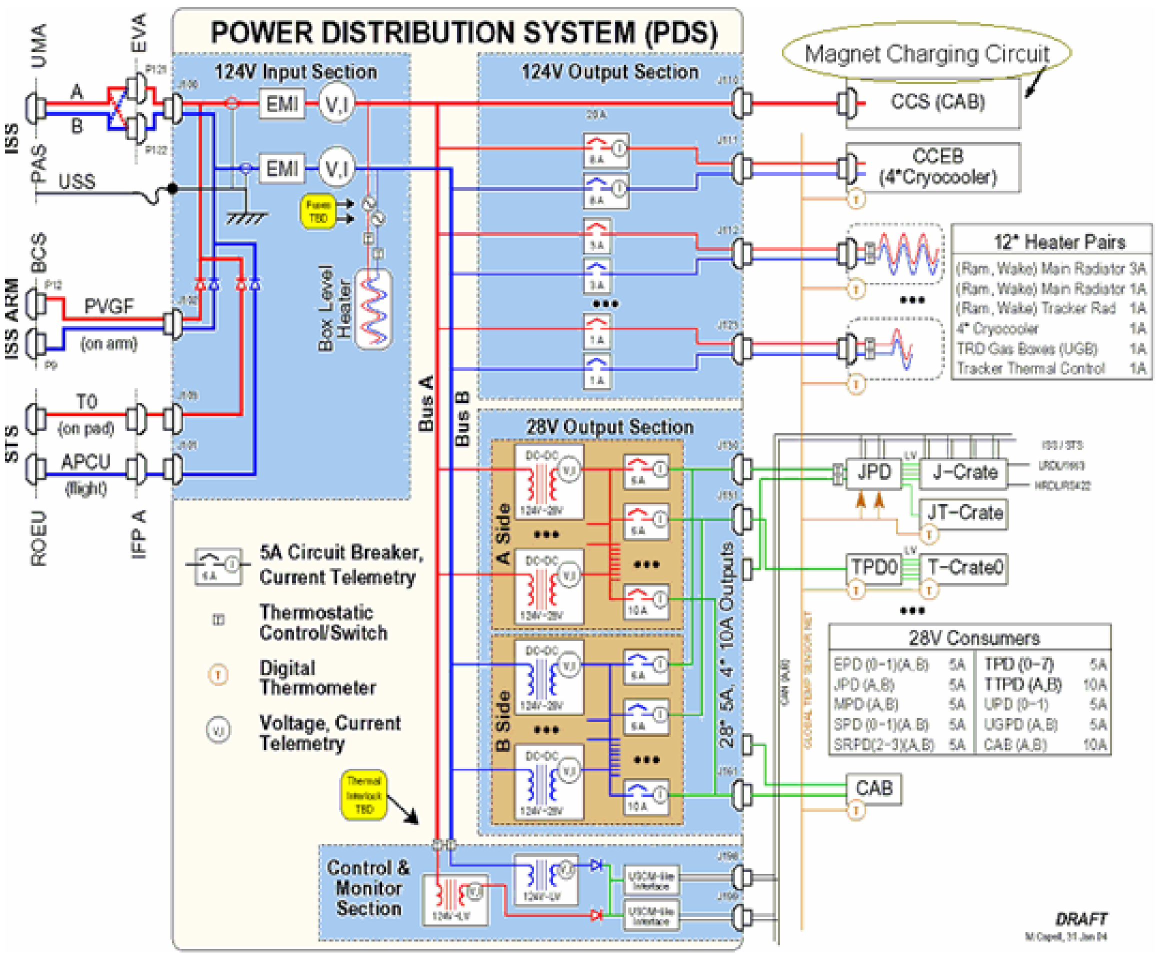
The 0.5 mT line is now retreating as the stray field starts to decay.

Conclusions

A small increase in stray field is observed when an unprotected dipole quench occurs together with a breakdown in the coil insulation. The 0.5 mT line moves out from about 4.5 m on the x-axis to nearly 6 m and on the other axes from 4 m to about 4.5 m. The 5 mT line on the other hand moves inwards slightly.

175 gauss is not exceeded where EVA activity may occur under this fault condition.

Attachment 4 – Cryomagnet Power Circuitry

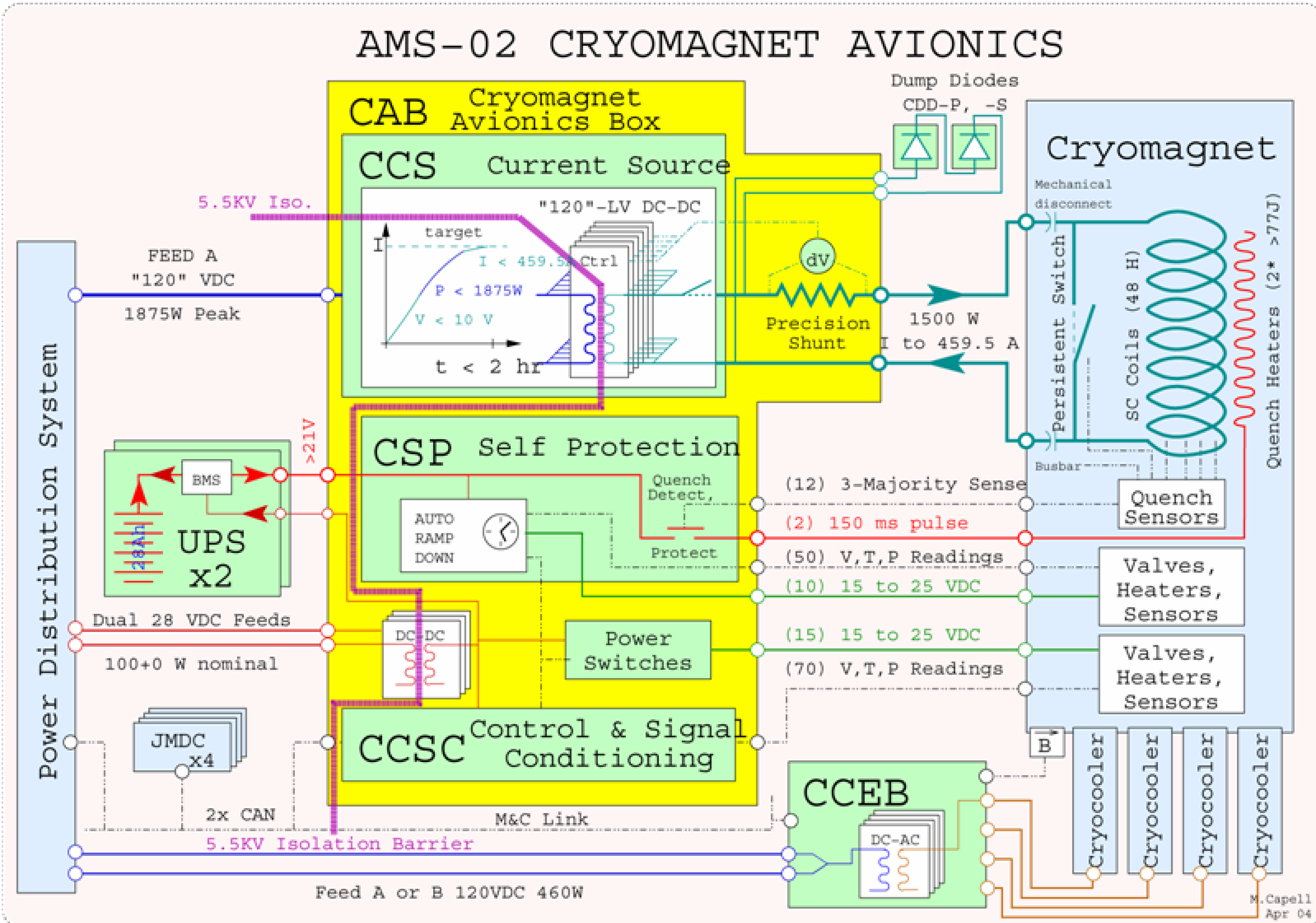


Power Availability for Charging the Cryomagnet.

Only the "A" bus is capable of charging the Cryomagnet, the "B" bus is isolated from the magnet charging circuit. An EVA accessible panel allows the crew to exchange cables to cross strap the bus "A" and bus "B" inputs to the other circuits within the AMS-02. This exchange does not result in bus "A" and bus "B" being interconnected.

Within the Shuttle only the T-0 line supplies power to bus "A" and is capable of charging the Cryomagnet. During this time the AMS-02 systems will be monitored for any unplanned charging activity. There is no planned charging of the AMS-02 Cryomagnet while in the Orbiter Payload Bay.

Default SSRMS Power is applied through connector P9.



CRYOMAGNETIC AVIONICS

-----Original Message-----
From: Steve Milward [mailto:stevemilward@spacecryo.co.uk]
Sent: Monday, April 05, 2004 11:01 AM
To: Martin, Trent
Cc: S M Harrison
Subject: Quench Pulse effects on ISS systems

Trent,

Further to our 'phone conversation earlier here are some thoughts:

During a quench the field decays with a time constant of 2 to 4 seconds. The voltage induced in any circuit will be proportional to the rate of change of flux through it and I suspect that for most circuits this will be small as the systems you are thinking of are in fields of 30 gauss or less. For example 30 gauss is 3 mT and a circuit 1 m in diameter perpendicular to the field has a flux of the order 3 mWb. If the field collapses in 1 second then the single turn voltage induced is 3 mV which sounds small to me.

I hope this helps.

Regards, Steve.

****

liable for direct, special, indirect or consequential damages arising from alteration of the contents of this message by a third party or as a result of any virus being passed on.

Space Cryomagnetics Ltd. Company No. 3950388. Registered in England and Wales at registered office: Building E1, Culham Science Centre, Culham, Abingdon, Oxfordshire OX14 3DB England. Tel: +44 (0)1865 409200. Fax: +44 (0)1865 409222. http://www.spacecryo.com/

Magnet Current Control and TM, Summary for Safety

31/03/2006

CAB design has included three protection barriers in series in order to not permit an actual current of the magnet higher than 459A. These are the protection barriers:

- SW protection (digital value)
- FPGA protection (digital value)
- Control electronics protection circuitry

The first SW protection prevent from any error of the operator command. In nominal case and typical conditions, it should be enough to guarantee that the maximum current of 459A is not exceeded at magnet level: 455.33A (SW limit) +3.5A due to the control electronics and protection error in WCA. Final SW limit value to be decided after testing. This barrier avoids continuous operation of the HW protection of the third barrier.

The second protection is used at FPGA (Field Programmable Gate Array) level. This protection barrier should work in case of a failure at CPU H/W or S/W level. The FPGA protection limit is 457A. This second barrier avoids also the continuous operation of the third barrier in case of internal failure of the active CPU.

The third protection is implemented in a majority voting configuration (three conditioning circuits of the control circuitry). The nominal value of this third protection is 455.5A. In case of failure, and in WCA up, the current limit of the third protection will be depending on the protection circuitry error (±1.5A) and the control electronics error (±2A). This represents an inaccuracy of ±3.5A for the third protection barrier, then 455.5A + 3.5A = 459A Max.

Performance Table of the Magnet Current Control

In the table below, the performances of the magnet current control have been adjusted to assure that the current passing through the magnet must never exceed the <u>absolute maximum value of 459A</u>, still in failure mode.

Performances Table of the Magnet Current Control			
Parameter	**Required by CCS Technical Spec**	**Performances in WCA**	**Failure Mode**
Normal output current control range in WCA up ↑	**(20A to 0.992 Imax)** **20A to 455.33A**	20A to 457.33A	N/A
Normal output current control range In Nominal Case		20A to 455.33A (*1)	N/A
Normal output current control range in WCA down ↓		20A to <u>452A</u> (*3)	N/A
Magnet Current Accuracy **• Long term output current repeatability** **• Output current measurement**	**< ±0.5%** **(*2)** **Electronics & Current Shunt Errors**	< ±0.5% (*2)	N/A
Max Current permitted in WCA, drift and trip circuit failures **Imax**	**459A**	457.33A	459A
SW protection digital value		455.33A (*1)	
FPGA protection digital value		457A	
Control Electronics protection value (This includes errors of the control and protection circuitries)		459A Max 455.5A Typical 452A Min	

(*1) Note that the upper value of the normal output current control range corresponds to 455.33A. This value is derived from the setting values permitted at SW level. Now, 455.33A is the SW protection digital value (upper limit corresponding to the maximum setting value permitted, in nominal case)

(*2) The error of ±0.5% required in the CCS technical specification includes the accuracy of the electronics and the current shunt.

(*3) See an explanation in paragraph below.

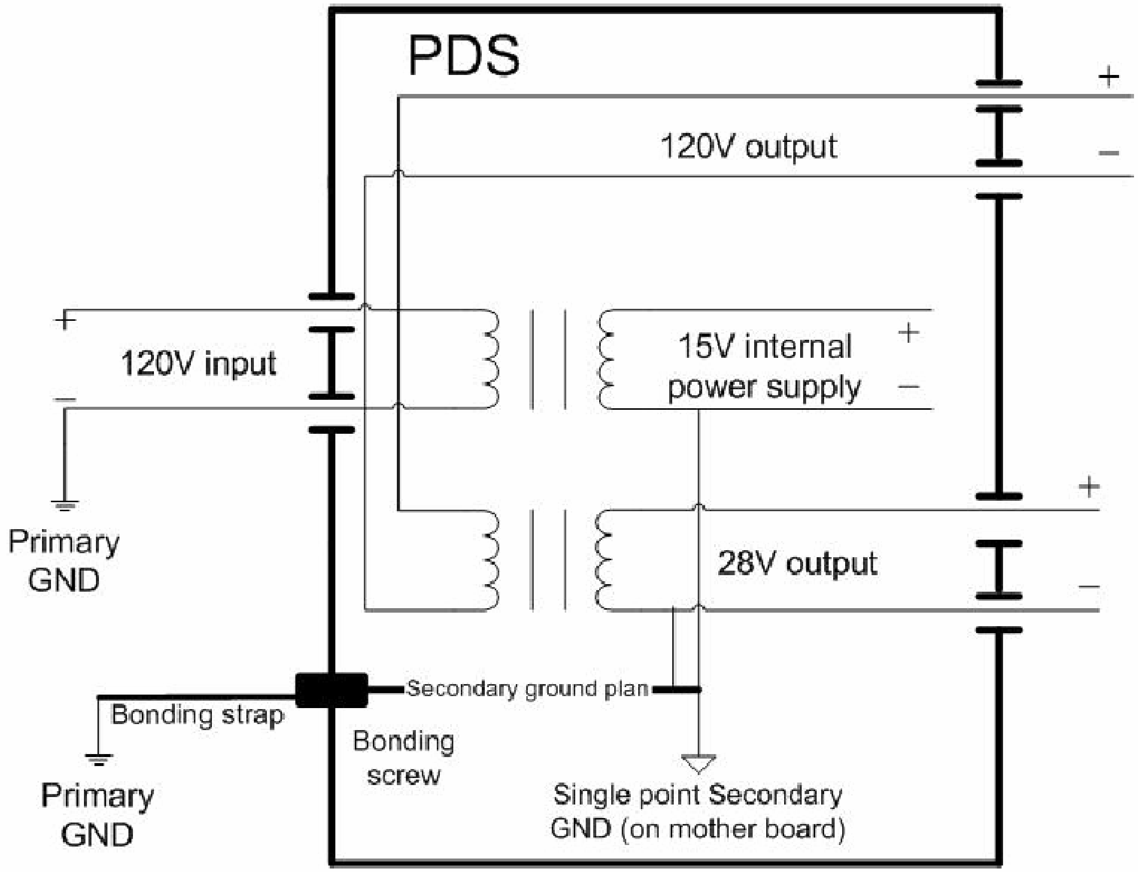
The performances are:
- (20A to 455.33A) in typical case
- (20A to 457.33A) in WCA max↑
- (20A to 452A) in WCA min↓

455.33A is the upper limit corresponding with the maximum setting value permitted at SW level, in typical case.
457.33A is the maximum current value, which should be controlled regarding a Worst Case Analysis going up.
452A is the minimum current value, which should be controlled regarding a Worst Case Analysis going down.

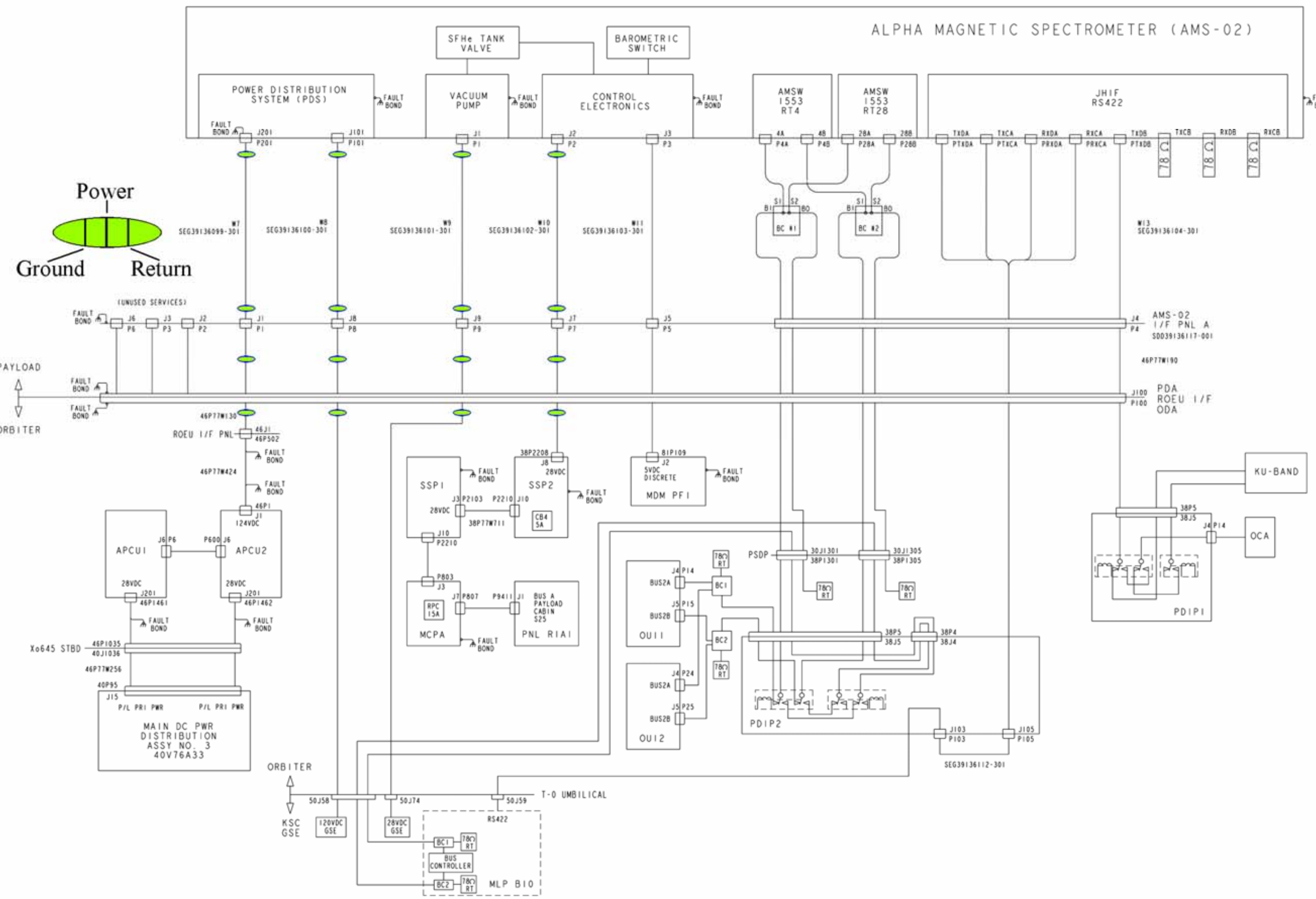
The conclusion is that regarding the present baseline, if the operator sends a setting value of 455.33A, the magnet will be charged at 455.33A typically, 457.33A max in WCA up, and 452A min in WCA down, or any other value between them. Nevertheless, the current TM will acquire the actual current of the magnet with accuracy better than ±2A.

The maximum error of current control electronics is also ±2A. However, at this value of current of 455.33A, it is necessary to take into account in WCA both contributions, the control electronics and protection circuitry. This is the reason why the minimum value of magnet could get 452A instead of 453.33A in WCA min (due to the clamping of the protection circuitry added to the control electronics error)

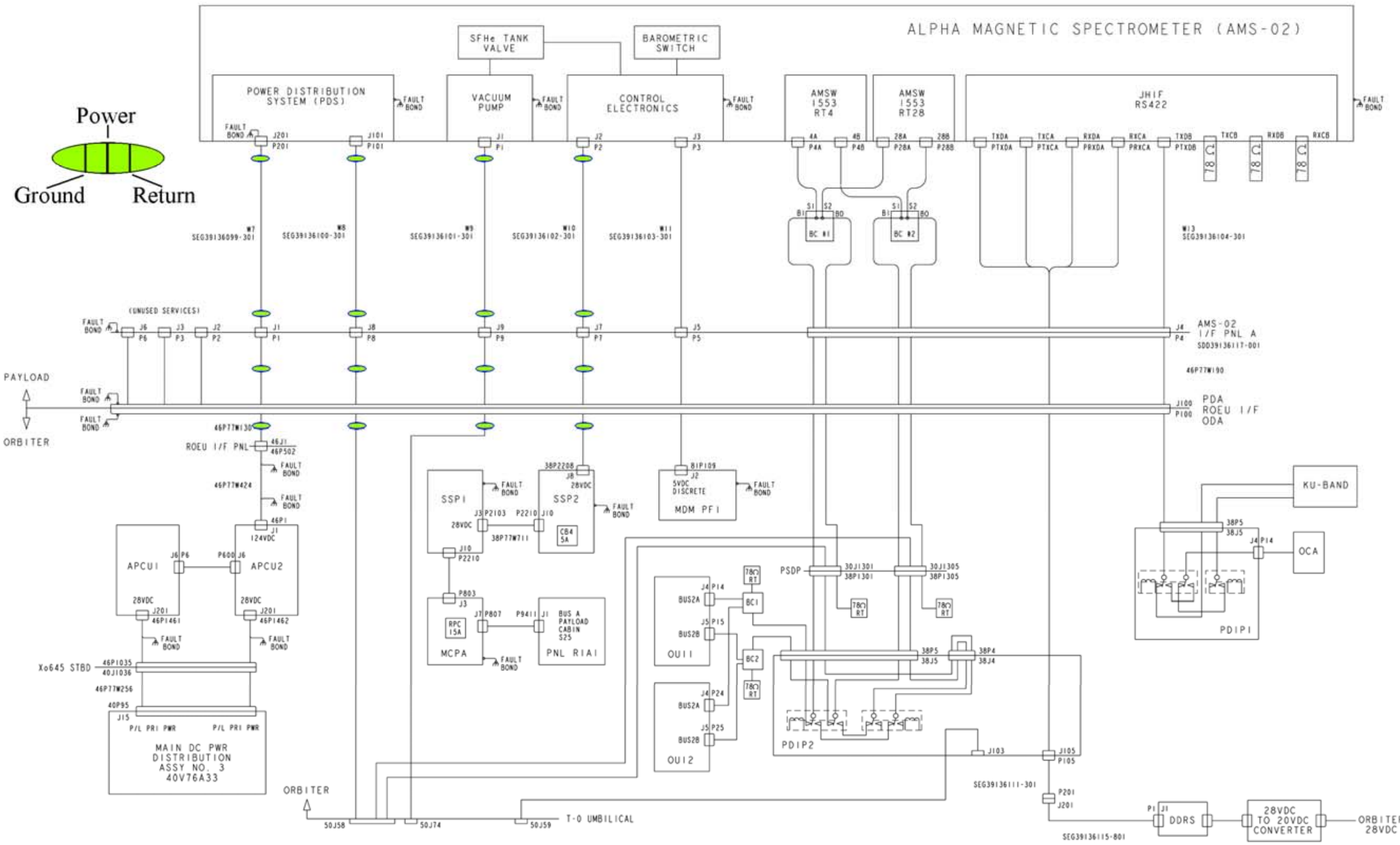
For example, if the operator sends a setting value of 454A, the magnet will be charged at 454A typically, 456A in WCA up and 452A in WCA down, then guaranteeing accuracy better than ±2A.



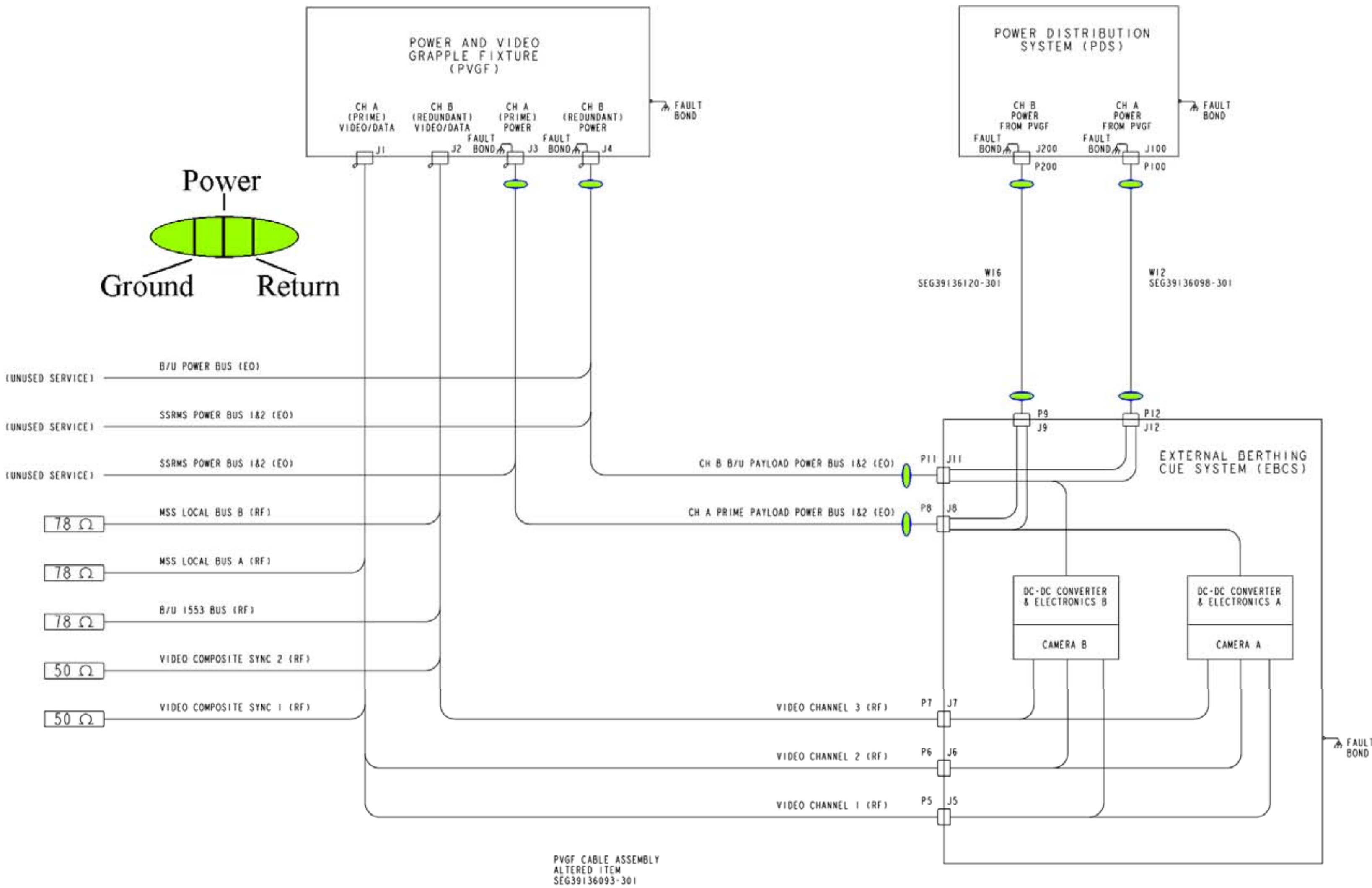
Principle Grounding Path for AMS-02 is through PDS system



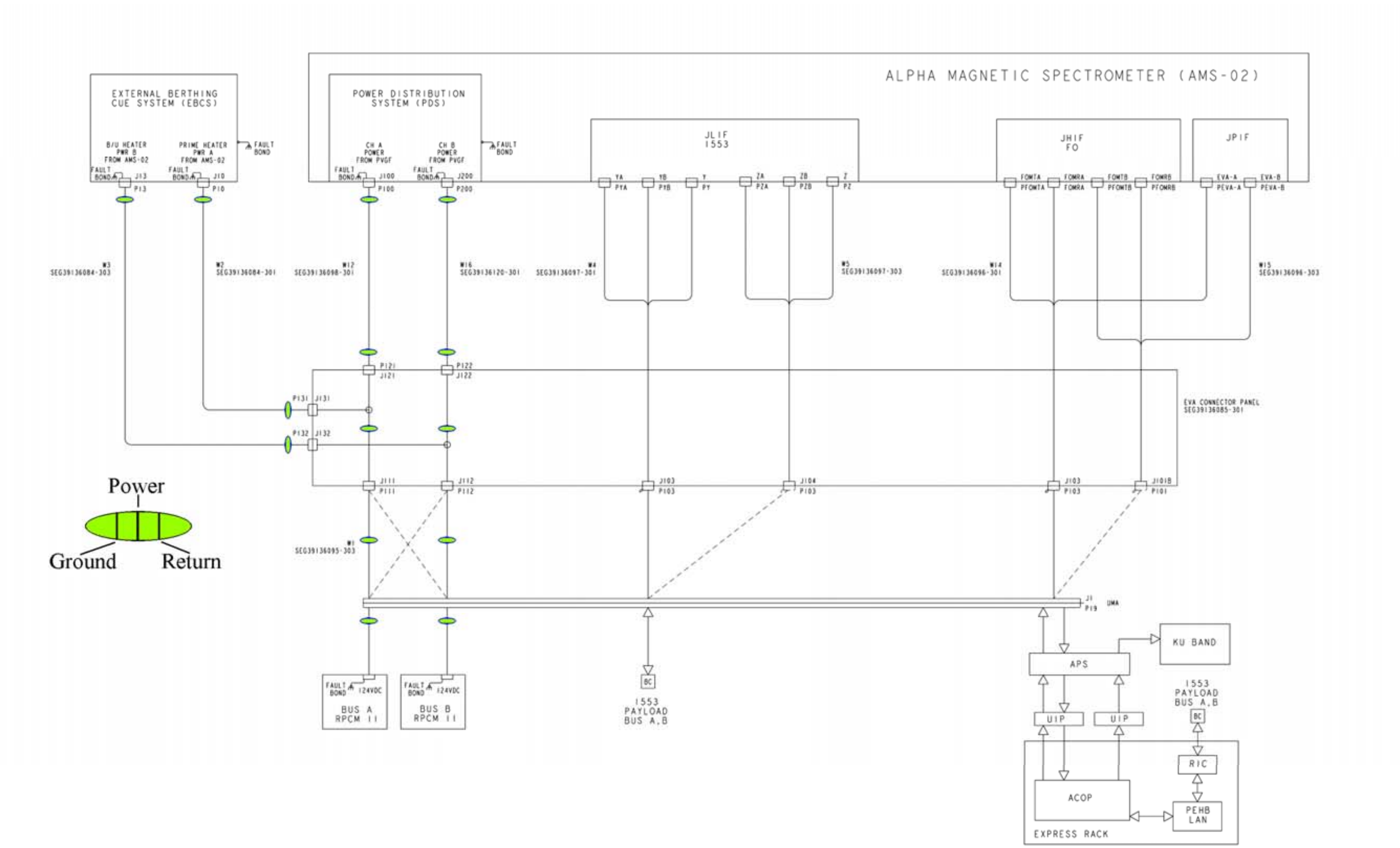
AMS-02 GROUNDING PATH WHILE ON THE PAD



AMS-02 GROUNDING PATH WHILE ON THE ORBITER DURING FLIGHT PHASE

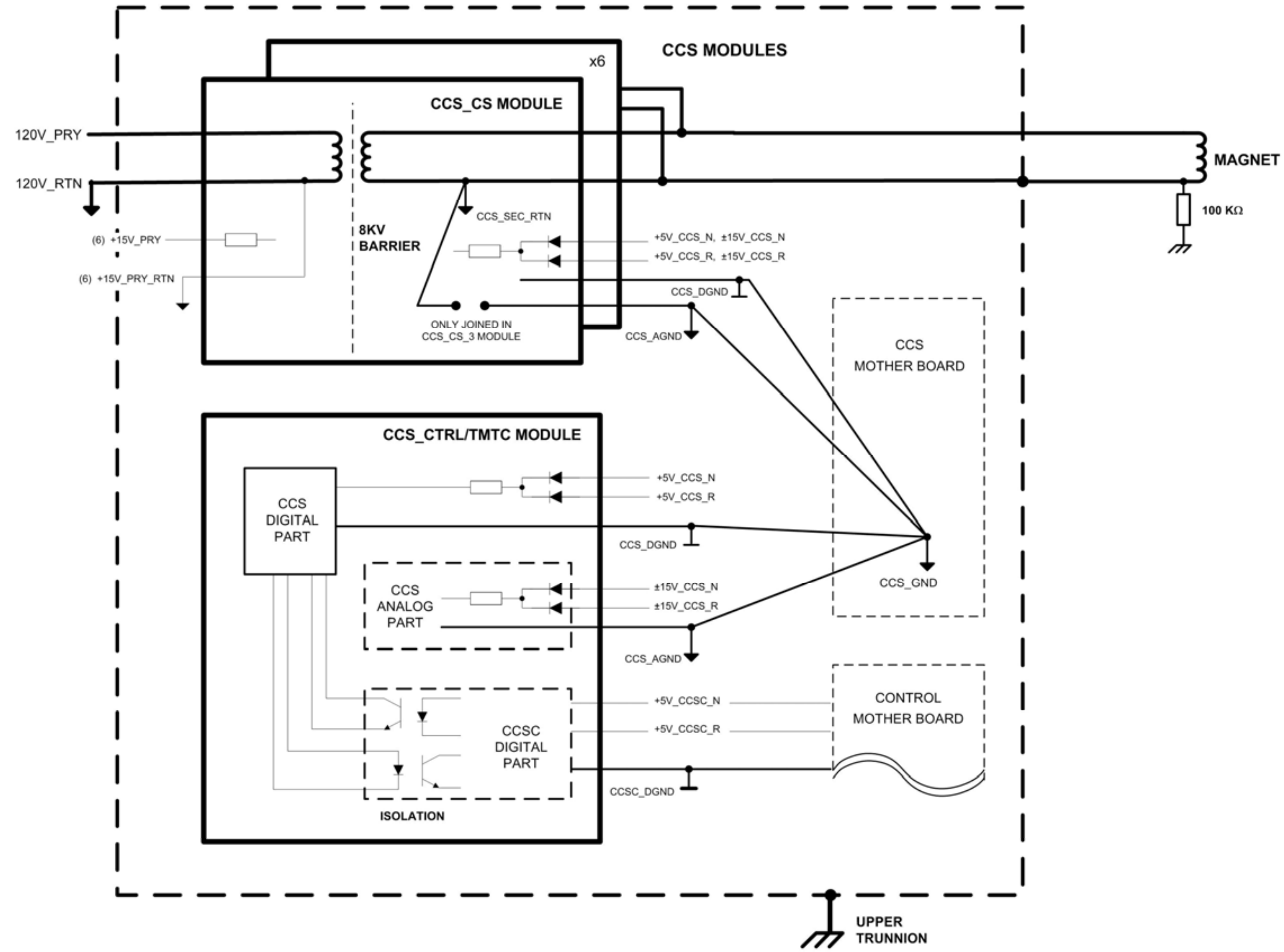


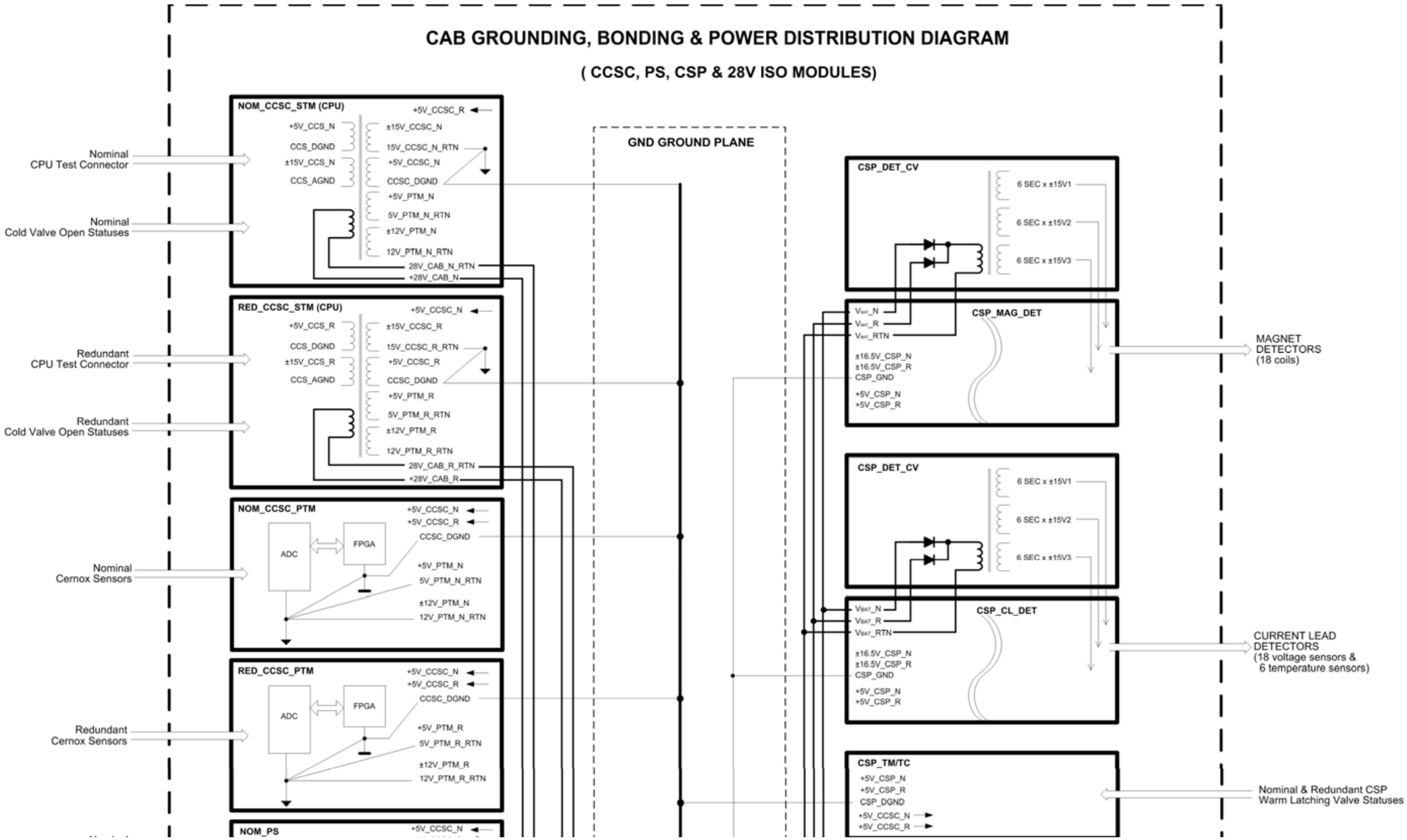
AMS-02 GROUNDING PATH WHILE ON THE ISS SSRMS

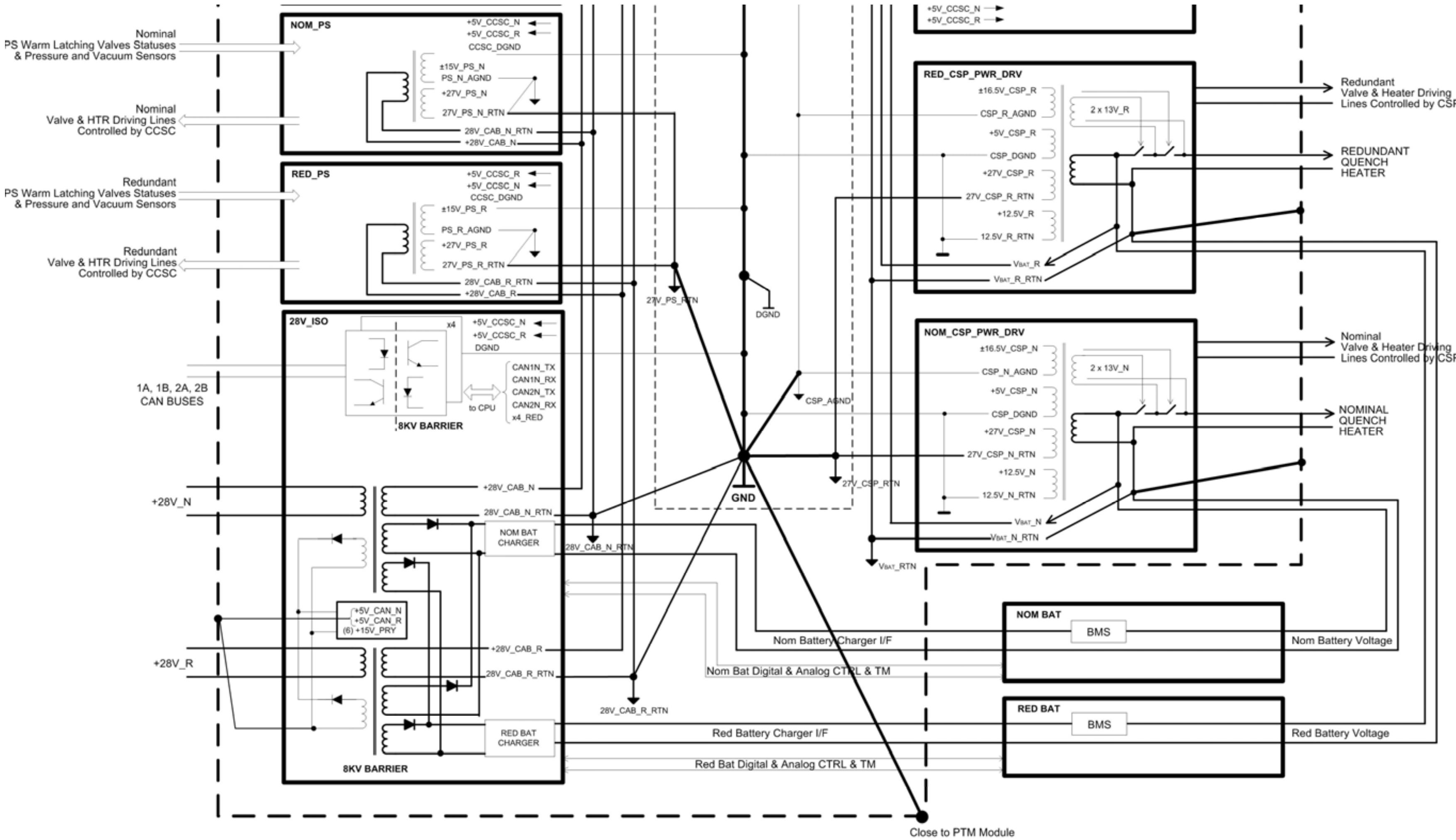


AMS-02 GROUNDING INTERFACE WHILE INSTALLED ON ISS PAS LOCATION

CAB GROUNDING, BONDING & POWER DISTRIBUTION DIAGRAM




CAB GROUNDING, BONDING & POWER DISTRIBUTION DIAGRAM
(CCSC, PS, CSP & 28V ISO MODULES)
NOM_CCSC_STM (CPU)
+5V_CCSC_R
+5V_CCS_N
CCS_DGND
±15V_CCS_N
CCS_AGND
±15V_CCSC_N
15V_CCSC_N_RTN
+5V_CCSC_N
CCSC_DGND
+5V_PTM_N
5V_PTM_N_RTN
±12V_PTM_N
12V_PTM_N_RTN
28V_CAB_N_RTN
+28V_CAB_N
Nominal
CPU Test Connector
Nominal
Cold Valve Open Statuses
RED_CCSC_STM (CPU)
+5V_CCSC_N
+5V_CCS_R
CCS_DGND
±15V_CCS_R
CCS_AGND
±15V_CCSC_R
15V_CCSC_R_RTN
+5V_CCSC_R
CCSC_DGND
+5V_PTM_R
5V_PTM_R_RTN
±12V_PTM_R
12V_PTM_R_RTN
28V_CAB_R_RTN
+28V_CAB_R
Redundant
CPU Test Connector
Redundant
Cold Valve Open Statuses
NOM_CCSC_PTM
ADC
FPGA
+5V_CCSC_N
+5V_CCSC_R
CCSC_DGND
+5V_PTM_N
5V_PTM_N_RTN
±12V_PTM_N
12V_PTM_N_RTN
Nominal
Cernox Sensors
RED_CCSC_PTM
ADC
FPGA
+5V_CCSC_N
+5V_CCSC_R
CCSC_DGND
+5V_PTM_R
5V_PTM_R_RTN
±12V_PTM_R
12V_PTM_R_RTN
Redundant
Cernox Sensors
NOM_PS
+5V_CCSC_N
GND GROUND PLANE
CSP_DET_CV
6 SEC x ±15V1
6 SEC x ±15V2
6 SEC x ±15V3
CSP_MAG_DET
VBAT_N
VBAT_R
VBAT_RTN
±16.5V_CSP_N
±16.5V_CSP_R
CSP_GND
+5V_CSP_N
+5V_CSP_R
MAGNET
DETECTORS
(18 coils)
CSP_DET_CV
6 SEC x ±15V1
6 SEC x ±15V2
6 SEC x ±15V3
CSP_CL_DET
VBAT_N
VBAT_R
VBAT_RTN
±16.5V_CSP_N
±16.5V_CSP_R
CSP_GND
+5V_CSP_N
+5V_CSP_R
CURRENT LEAD
DETECTORS
(18 voltage sensors &
6 temperature sensors)
CSP_TM/TC
+5V_CSP_N
+5V_CSP_R
CSP_DGND
+5V_CCSC_N
+5V_CCSC_R
Nominal & Redundant CSP
Warm Latching Valve Statuses



CAB GROUNDING AND BONDING DIAGRAMS